

## FIELD STUDY OF PLANT SURVIVAL AS AFFECTED BY AMENDMENTS TO BENTONITE SPOIL

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**ABSTRACT.**—Efforts to reclaim amended and raw bentonite spoils with six plant species (two forbs, three shrubs, and one tree) were evaluated over a 4-year period. Plant species included fourwing saltbush (*Atriplex canescens* [Pursh] Nutt.), big sagebrush (*Artemisia tridentata tridentata* Nutt.), Rocky Mountain juniper (*Juniperus scopulorum* Sarg.), Russian olive (*Elaeagnus angustifolia* L.), common yarrow (*Achillea millefolium* L.), and scarlet globemallow (*Sphaeralcea coccinea* [Pursh] Rydb.). Spoil treatments included addition of gypsum, sawdust, perlite, straw, and vermiculite; the control treatment was unamended. Fourwing saltbush had 52% survival across all spoil treatments, with greatest survival occurring on perlite-treated spoil (80%), followed by gypsum (70%) and vermiculite amendments (70%). Survival of other plant species ranged from 0 to 3% averaged across all treatments after 4 years. No differences in plant survival occurred among amendments when all species were considered.

*Key words:* shrubs, forbs, trees, Wyoming, mining, reclamation.

Bentonite, a montmorillonite clay, is a term referring to an altered deposit of volcanic ash (Barchardt 1977). In the northern Great Plains, bentonite is strip-mined from the Cretaceous marine Pierre and Mowry shale and Belle Fourche formations. Because of the spoils' saline sodic quality, high shrink-swell characteristics, limited internal drainage, arid and semiarid climate of the region, and absence of irrigation water, attempts at revegetation have faced restrictive problems (Hemmer et al. 1977, Bjugstad 1979).

In the absence of drainage and leveling possibilities, Russell (1973) suggested the planting of salt-tolerant *Atriplex* species. Voorhees et al. (1987) reported successful growth of rillscale (*A. suckleyi* [Torrey] Rydb.), a native annual, on bentonite mine spoil with amendments and supported use of this species for early revegetation on such spoils. Nutritional qualities of rillscale are generally adequate for livestock and wildlife (Voorhees 1990). Sieg et al. (1983) also reported that rillscale was the most successful invader of bentonite-mined land spoil in southeastern Montana. Other investigators using various species of plants (Hemmer et al. 1977, Bjugstad 1979, Dollhopf et al. 1980, Dollhopf and Bauman 1981, Smith et al. 1985, 1986, Voorhees et al. 1987) have reported varying degrees of success on bentonite mine spoils

using topsoil and spoil amendments to promote growth and establishment of plants. However, with the limited quality and quantity of topsoil on shale overburden of bentonite mine lands, a realistic and practical approach is to use salt- and drought-tolerant plants (Shannon 1979), fertilizers, and both organic and chemical amendments on raw spoils. Organic and chemical amendments are primarily intended to promote development and aggregation of the spoil material and to ameliorate the dispersion effect of excessive sodium.

In an earlier greenhouse study, Uresk and Yamamoto (1986) showed that salt- or drought-tolerant plants can survive in amended or untreated bentonite mine spoil. The objective of this study was to obtain field verification of the greenhouse study and to test effects of amendments on raw bentonite mine spoil for survival of salt- and drought-tolerant plants.

### MATERIALS AND METHODS

Study plots are located near Upton, Wyoming, on property owned by the American Colloid Company. Average precipitation is 380 mm per year, with highest rainfall occurring during the period from May through July. Average annual air temperature is 6°C, with an average low of -17°C in January and an

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average high of 23°C in July. The climate can be characterized as dry, hot, and windy in the summer and windy and cold in the winter. Stands of ponderosa pine (*Pinus ponderosa* Laws.) and sagebrush (*Artemisia*)/grass vegetation characterize areas around the bentonite mines. Bentonite mine spoils are essentially derived from the Mowry shale formation. Study plot surfaces were barren with 15 cm of loose shale spoil or exposed Mowry shale beds. These shale spoils are extremely hard and crusty when dry. Mowry shale is classed as siliceous shale (Pettijohn 1957), with an abnormally high silica content of 85% vs. 58% for normal shales. Its siliceous character is attributed to its volcanic ash origin (Rubey 1929).

Uresk and Yamamoto (1986) previously reported on the spoil properties (0–20 cm sampling depth) of the study site. Spoil is adequate in NPK status with nitrate nitrogen at 19 kg/ha, ammonia-nitrogen at 55 kg/ha, phosphorus and potassium at 39 µg/g and 170 µg/g, respectively. Soluble salt concentrations vary markedly, but the spoils are saline (EC of 9.2 mmhos/cm) and sodic (SAR 33.1). Spoil pH averaged 6.9 but ranged from 4.1 to 8.0. X-ray diffraction of bentonite spoil revealed a mixture of silicate clay types with a dominance of illite based on the CEC of 30 meq/100g, rather than montmorillonite as sometimes believed (Uresk and Yamamoto 1986). Other clays included montmorillonite and kaolinite. Additional information on chemical characteristics of raw bentonite spoil from the study area is reported by Voorhees et al. (1987).

Five different amendments to raw spoil materials were applied in 1979 (Table 1). Four spoil treatments included ponderosa pine sawdust, wheat straw, perlite, and vermiculite.

Fertilizer (NPK, 11-5-6) was added at 84 kg/ha to all treatments except the control. Additional nitrogen (dry pellet) was added to sawdust and straw spoil treatments at 12 kg/mt and 8 kg/mt, respectively, at time of planting. Each amendment was mixed with bentonite spoil at a 50:50 volume ratio with added gypsum at 10 mt/ha-30 cm depth. The fifth treatment, without any physical amendment, was gypsum at 20 mt/ha-30 cm depth (USSLS 1954). The sixth treatment was a control (untreated). All treatments except the control were surface mulched with ponderosa pine woodchips to a depth of 2 cm.

Six plant species were selected on the basis of drought and saline-alkali tolerance (Gill 1949, Wright and Bretz 1949, McKell 1978): fourwing saltbush (*Atriplex canescens* [Pursh] Nutt.), big sagebrush (*Artemisia tridentata tridentata* Nutt.), Rocky Mountain juniper (*Juniperus scopulorum* Sarg.), Russian olive (*Elaeagnus angustifolia* L.), common yarrow (*Achillea millefolium* L.), and scarlet globemallow (*Sphaeralcea coccinea* [Pursh] Rydb.). Russian olive and Rocky Mountain juniper were 3- and 1 1/2-year-old bare root seedlings, respectively; the remaining species were 1-year-old container-grown seedlings. All plants were planted in mid-May 1979. Survival of plants was evaluated twice per year (spring and fall) from 1979 to 1982.

The experimental design was a 6 × 6 (6 species × 6 treatments) factorial arrangement with two replications accomplished through randomized blocks. Each block consisted of 6 treatments (columns) per species with 10 plants per treatment. Twenty plants for each species were evaluated per treatment in this design. Plants were spaced 1 m apart, within and between columns. Each plant was planted

TABLE 1. Experimental design with six treatments and added supplements.

| Supplements                      | Treatments           |        |          |         |         |             |
|----------------------------------|----------------------|--------|----------|---------|---------|-------------|
|                                  | Control <sup>1</sup> | Gypsum | Sawdust  | Perlite | Straw   | Vermiculite |
| NPK(11-5-6) 84 kg/ha             |                      | X      | X        | X       | X       | X           |
| N                                |                      |        | 12 kg/mt |         | 8 kg/mt |             |
| Gypsum<br>(10 mt/ha-30 cm depth) |                      | X      | X        | X       | X       | X           |
| Mulch (2 cm depth)               |                      | X      | X        | X       | X       | X           |

<sup>1</sup>Raw bentonite spoil only

to the depth of the root crown in a hole 30 cm in diameter and 35 cm deep with the bottom 5 cm filled with sawdust. The hole was then backfilled with spoil, chemical and physical amendments. Each plant was gently watered (deionized tap water) to saturation immediately after planting. The study site was visited once a week for watering (1 L per plant) during the first month after transplanting and biweekly thereafter from May to September for two growing seasons (1979 and 1980).

Differences in survival among species and treatments were analyzed by chi-square procedures for comparison of proportions from many samples (Fleiss 1973). All differences were evaluated at  $\alpha = .10$ .

### RESULTS AND DISCUSSION

Mortality of all plant species was very high after the first growing season. All Russian olives died after 2 weeks, and further documentation of this species was discontinued. (1) Survival and growth of these species on field plots of bentonite spoil was different from that recorded in the greenhouse (Uresk and Yamamoto 1986). (2) Fourwing saltbush performed well, with an overall survival rate of 52% after four growing seasons (Table 2). Survival rate for this species was greatest on the perlite spoil amendment (80%) followed by gypsum (70%) and vermiculite (70%) amendments. Survival of yarrow, scarlet globemallow,

and big sagebrush was very low but did indicate some adaptability to amended spoils.

The halophytic capabilities of many members of the genus *Atriplex* are well documented in literature (Waisel 1972, Osmond et al. 1980, Richardson and McKell 1980, Tiedemann et al. 1984). A 40% survival of fourwing saltbush on the control treatment (Table 2) demonstrates the natural adaptability of this species to saline-alkali conditions. Survival rates increased 40 percentage units when the perlite amendment was utilized. Gypsum and vermiculite showed survival rates increased 30 percentage units but were not significantly different from the control. This indicated that some gains in survival could be attained by amendment of raw bentonite spoil, although not significant at  $P = .10$ . In this study overall plant survival was greatest with perlite.

Adding sawdust has been the most accepted amendment for reclaiming raw bentonite spoils; however, there are differences in opinion on the desirability of using sawdust. It has shown some beneficial results, particularly when applied as mulch and eventually worked into the soil (Lunt 1955). Others have tried applying sawdust or shavings to their soils with disappointing and sometimes disastrous results (Lunt 1955). Most researchers have observed no toxicity when adequate nitrogen was used with sawdust or other wood products (Allison and Anderson 1951). However, tannins, resins, and secondary compounds

TABLE 2. Survival of transplanted plant species in bentonite mine spoil treatments after four growing seasons at Upton, Wyoming.

| Species                | Spoil treatment  |                  |                  |                 |                 |                  | Average survival <sup>1</sup><br>(%) |
|------------------------|------------------|------------------|------------------|-----------------|-----------------|------------------|--------------------------------------|
|                        | Control (%)      | Gypsum (%)       | Sawdust (%)      | Perlite (%)     | Straw (%)       | Vermiculite (%)  |                                      |
| Yarrow                 | 0                | 0                | 15               | 5               | 0               | 0                | 3 <sup>a</sup>                       |
| Rabbitbrush            | 0                | 0                | 0                | 0               | 0               | 0                | 0 <sup>a</sup>                       |
| Scarlet globemallow    | 0                | 0                | 0                | 0               | 0               | 5                | 1 <sup>a</sup>                       |
| Fourwing saltbush      | 40 <sup>ab</sup> | 70 <sup>ab</sup> | 30 <sup>ab</sup> | 80 <sup>b</sup> | 20 <sup>a</sup> | 70 <sup>ab</sup> | 52 <sup>b</sup>                      |
| Big sagebrush          | 0                | 0                | 0                | 10              | 10              | 0                | 3 <sup>a</sup>                       |
| Rocky Mountain juniper | 0                | 0                | 0                | 0               | 0               | 0                | 0 <sup>a</sup>                       |
| Average survival       | 7 <sup>a</sup>   | 12 <sup>a</sup>  | 8 <sup>a</sup>   | 16 <sup>a</sup> | 5 <sup>a</sup>  | 13 <sup>a</sup>  | 10                                   |

<sup>1</sup>Means in row or column followed by the same letter are not different at  $\alpha = .10$ . Absence of letters indicates no statistical significance.

## PERCENT SURVIVAL

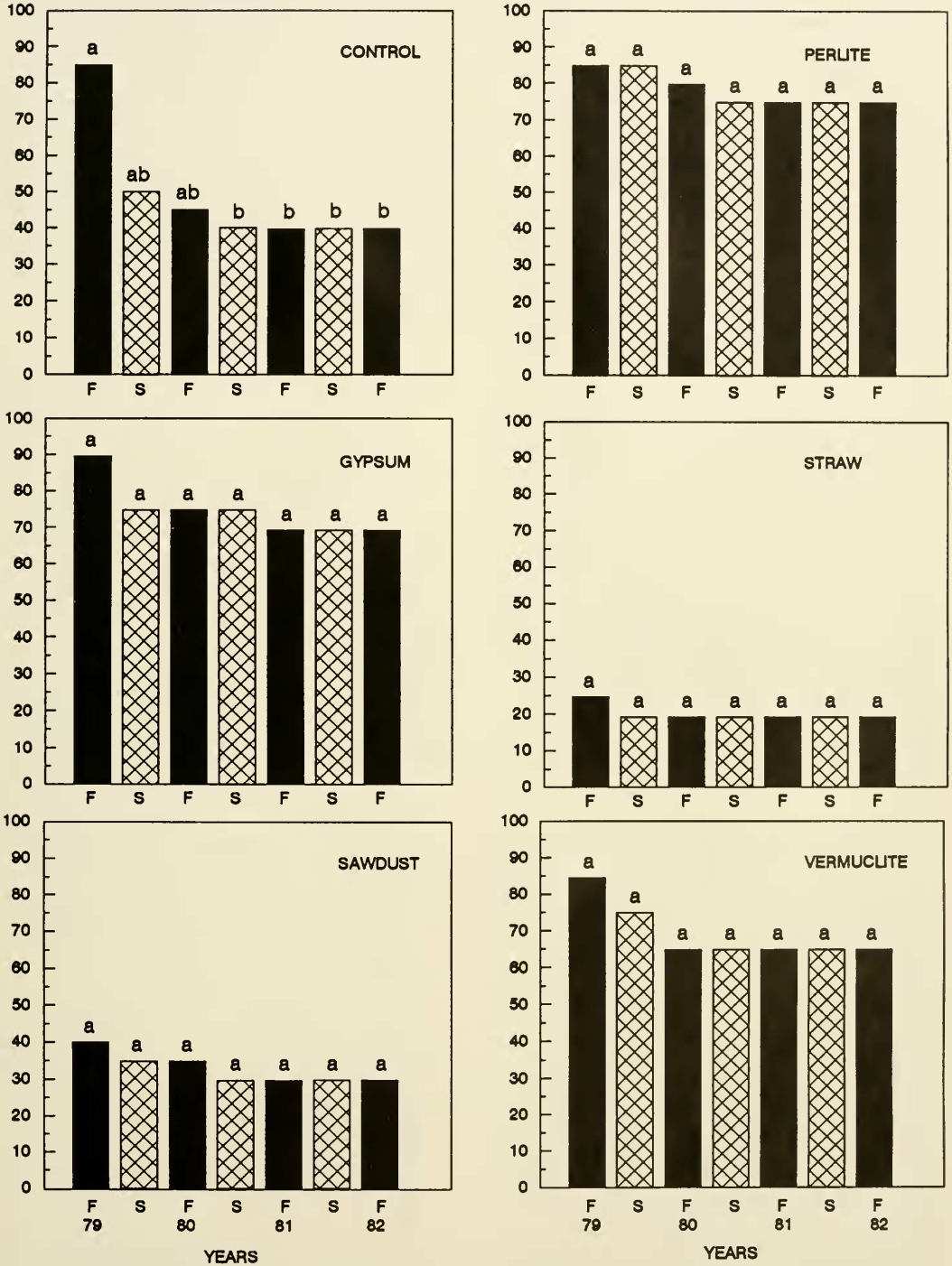


Fig. 1. Survival of fourwing saltbush during fall (F) and spring (S) measurements, 1979-82, at  $\alpha=.10$ .

from fresh sawdust are possibly toxic to plants. Also, increased soil acidity from sawdust may decrease survival (Allison and Anderson 1951). Sawdust added to raw bentonite spoils increased water infiltration (Voorhees 1986). Infiltration rates have not been evaluated against perlite or vermiculite as amendments. In addition, Voorhees et al. (1987, 1991) and Voorhees and Uresk (1990) found that bentonite spoil amended with sawdust, alone or in combination with other amendments, increased growth of rillscale through two growing seasons. Schuman and Sedbrook (1984), Smith et al. (1985), and Belden et al. (1990) showed that sawdust added to spoil, with wood chips added to the surface, promoted vegetation establishment over a 4-year period.

Measurements of spoil pH from the fourwing saltbush plots after four growing seasons ranged from 6.1 to 6.8 for the various treatments. These values were generally 1–2 units lower than pH values of bentonite spoils measured at the termination of the greenhouse study (Uresk and Yamamoto 1986). Lowest pH values were found in samples from plots that had been amended with sawdust, straw, or vermiculite. Since vermiculite amendment was associated with higher survival trends of fourwing saltbush, and sawdust and straw amendments with the lowest survival, pH may not have been a factor in survival of fourwing saltbush.

Examination of survival for fourwing saltbush (Fig. 1) showed that greatest mortality for all treatments except the control occurred during the first growing season prior to fall evaluation. Thereafter, no significant mortality occurred, except on the control treatment. Greatest survival rates of fourwing saltbush were with perlite, vermiculite, and gypsum. These materials and their mixes are well known in plant nurseries and in the horticultural industry as pot mixes. Apparently, they mix well with bentonite spoils, improve plant survival rates, and may indicate that water infiltration, aeration, and bulk density characteristics are improved with their addition to spoils.

With the exclusion of fourwing saltbush, overall average survival rates of selected plant species across amendment-treated spoils after four growing seasons were 0–3%. Fourwing saltbush demonstrated a natural adaptability

to establishment on saline-alkali bentonite spoil, with an overall survival rate of 52%. Perlite, vermiculite, and gypsum amendments enhanced survival rates for fourwing saltbush. Sawdust and straw amendments did not increase survival as much as perlite or vermiculite amendments, but plant survival on these amendments was very stable. Sawdust and straw are materials that are readily available in the Black Hills and in bentonite mining areas. Further experimentation with differing rates, type of applications, bed preparations, and times of planting and seeding are needed, especially for shrubs and forbs.

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